INSECT DAMAGE, CONE DIMENSIONS, AND SEED PRODUCTION IN CROWN LEVELS OF PONDEROSA PINE

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Abstract.— Insect damage to second-year cones was generally not significantly different between crown levels, but was significantly different among areas and among trees within areas for *Conophthorus*, *Megastigmus*, and *Cydia*. Both cone length and width were not significantly different between lower and middle crown, but cone length was significantly greater in the upper crown. Seeds per cone ranged from 34 to 66, but the percent of sound seed per cone varied significantly according to the amount of insect damage.

Cone and seed insects of ponderosa pine, *Pinus ponderosa* Douglas ex Lawson, have received little attention in the Southwest. In southern New Mexico Kinzer et al. (1972) identified the most common insects associated with ponderosa pine cones and determined the extent of their damage. In California Koerber (1967) identified the insect complex affecting ponderosa pine seed production and assessed the incidence of damage by the more important species. Between these two locations, little work had been done until an initial survey by Ragenovich et al. (1981) confirmed the presence of the most common species found by Kinzer et al. (1972) and determined the extent of their damage. A more extensive study by Schmid in 1982 had to confine sampling to that portion of the lower crown within reach of a step ladder. The question naturally arose as to whether the incidence of insect damage was different among crown levels. The present study determined the incidence of insect damage in second-year cones from different crown levels within the same tree; it also determined the dimensions of cones and their seed production.

Methods

Maturing pine cones were collected from 10 locations on the Coconino and Kaibab National Forests (southern part) in northern Arizona during September 1982 (Fig. 1). Sixteen cones were randomly pruned from the lower and middle crowns of each of 10 co-dominant or dominant trees at each of 8 locations. At 2 locations, cone-bearing trees were either felled or climbed by Forest Service personnel, and cones were collected also from the upper crowns, which are normally unreachable with a pole pruner. The cones were sacked, labeled by tree number, crown level, and location, and placed in cold-storage units in Flagstaff.

To determine the percentage of seeds damaged by insects, each cone was dissected.

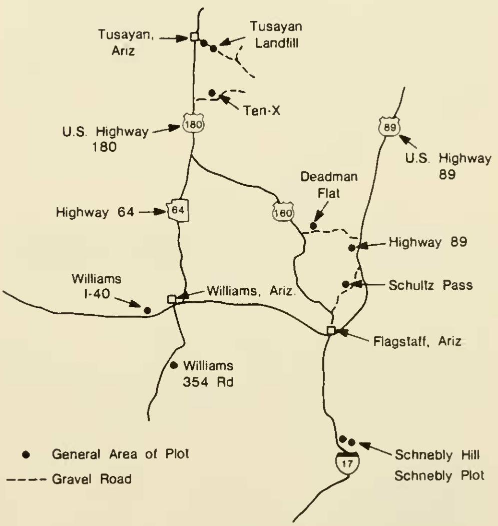

Fig. 1. Location of cone collection areas on the Coconino and Kaibab national forests.

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Cone length and width, and number of sound, hollow, and insect-damaged seeds were recorded. The percentage of seeds damaged by insect species was determined for each cone. Because *Conophthorus* and *Dioryctria* destroyed 100% of the seeds in each infested cone nearly all the time and *Megastigmus* and *Cydia* damaged variable percentages in each cone, the percentage of cones damaged by *Conophthorus* and *Dioryctria* and the percentage of seeds per cone damaged by *Megastigmus* and *Cydia* were each subjected to analysis of variance testing for significant variation among locations and trees and between crown levels ($\alpha = 0.05$). Prior to analysis, homogeneity of variance was evaluated for each set of data and, where nonhomogeneous variance occurred, the data were transformed using either an arcsine, square root, or square transformation and then the analysis was performed. Tukey's multiple range test was used to determine which mean values were significantly different from each other when the ANOV showed significant differences occurring. Confidence intervals (0.95) were computed for each mean using the Bonferroni method. Means and confidence intervals were then back-transformed to derive the information presented in the tables. Entries in Table 4 are based on untransformed data and variations among individual tree averages.

Results and Discussion

Insect Damage

The amount of insect damage to cones and seeds was not significantly different between the lower crown and the middle or upper crown for either *Conophthorus ponderosae* Hopkins, *Dioryctria* spp., or *Cydia* sp. and was significantly greater in the upper levels for *Megastigmus albifrons* Walker in only one location. Percent of cones damaged by *Conophthorus* (Table 1) varied significantly among areas and among trees within areas, but did not vary significantly for *Dioryctria*. Similarly, the percentage of seeds per cone damaged by *Megastigmus* and *Cydia* (Table 2) varied significantly among areas and among trees within areas for both species.

The insignificant differences in insect damage between crown levels indicate that cones can be collected from any crown level to determine the incidence of damage for the tree. The significant differences in insect damage among areas and among trees within areas indicate other factors are influencing the degree of damage among trees and locations.

Conophthorus damage was substantial in three locations (Table 1). Although the mean values for all crown levels did not approach the 50% damage level cited by Pearson (1950) in the three locations, percent damage was 45% in the middle crown at the U.S. Highway 89 location. Because cone damage was greatest at the three highest locations and at the lowest location, elevation might be thought to be an important factor. However, other past and current cone studies have indicated an especially high incidence of *Conophthorus* damage at the Deadman Flat and U.S. Highway 89 locations, locations producing several consecutive cone crops. These observations suggest that locations producing cone crops each year may support a

TABLE 1. Mean percentage of cones infested by *Conophthorus* and *Dioryctria*, Coconino and Kaibab national forests, Arizona, 1982.

National forest/Location	Elevation	*Conophthorus*	*Dioryctria*
	m	$\bar{X}$(95% confidence interval)	
Coconino National Forest			
Schnebly Hill	1980	<1 (0–1)	0
Schnebly Plot	1980	<1 (0–1)	0
U.S. Highway 89	2195	39(12–66)	1(0–3)
Deadman Flat	2290	15 (6–24)	1(0–2)
Schultz Pass	2465	35(14–56)	1(0–3)
Kaibab National Forest			
U.S. Highway I-40	1800	31(13–50)	1(0–2)
Ten-X	2025	2 (0–5)	0
Tusayan	2045	1 (0–3)	0
Tusayan Landfill	2045	8 (0–16)	1(0–3)
Williams 354 Road	2165	0	0

TABLE 2. Mean percentage of seeds per cone infested by *Megastigmus* and *Cydia*, Coconino and Kaibab national forests, Arizona, 1982.

National forest/Location	Elevation	*Megastigmus*	*Cydia*
	m	X̄(95% confidence interval)	
Coconino National Forest			
Schnebly Hill	1980	1 (1–2)	6 (0–10)
Schnebly Plot	1980	1 (<1–1)	0
U.S. Highway 89	2195	77(72–81)	16(10–20)
Deadman Flat	2290	31(28–35)	11 (7–13)
Schultz Pass	2465	22(19–26)	5 (0–8)
Kaibab National Forest			
U.S. Highway I-40	1800	3 (2–4)	9 (0–13)
Ten-X	2025	2 (1–3)	9 (5–11)
Tusayan	2045	2 (2–3)	4 (1–6)
Tusayan Landfill	2045	5 (4–6)[a]	3 (0–4)
Williams 354 Road	2165	3 (1–4)	14 (5–20)

[a]Upper crown levels had a significantly greater percent of infested seeds.

greater *Conophthorus* population and thereby sustain a greater incidence of damage. Beetle populations in such areas would spend less time searching for new cones and would sustain less dispersal mortality, so the probability of cone damage would be greater. In contrast, locations producing cone crops every 3–5 years would sustain lesser damage to each crop because adults of successive generations would have to search more extensively to find trees with cones and would therein be subject to greater mortality.

Megastigmus caused the greatest seed loss of any insect, including *Conophthorus*. Damage was greatest on the same Coconino National Forest locations as where significant *Conophthorus* damage occurred. The hypothesis regarding greater *Conophthorus* damage being associated with continuous cone production areas also appears pertinent to *Megastigmus*.

Cone Dimensions

Cone length varied significantly among areas and among trees within the same area, but cone width did not vary significantly among areas or trees (Table 3). Both cone length and width were not significantly different between the lower and middle crowns in all areas, but cones in the upper crowns were longer and wider than cones from the lower crowns in the two areas where cones were gathered from the upper crown. Within the range of elevations from which cones were collected, neither cone length nor width exhibited a trend with elevation, so cone dimensions appear to be influenced more by stand and site conditions than by elevation.

Seed Production

Total seeds per cone ranged from 34 to 66 (Table 4). Compared to the 31 seeds per cone

TABLE 3. Mean length and width of ponderosa pine cones, Coconino and Kaibab national forests, Arizona, 1982.

National forest/Location	Elevation	Length	Width
		X̄ (95% confidence interval)	
Coconino National Forest	*m*	*cm*	*cm*
Schnebly Hill	1980	8.1(7.8–8.3)	3.4(3.3–3.4)
Schnebly Plot	1980	8.1(7.9–8.3)	3.2(3.1–3.3)
U.S. Highway 89	2195	6.2(6.0–6.4)	3.3(3.2–3.4)
Deadman Flat	2290	8.1(7.9–8.4)	4.0(3.8–4.1)
Schultz Pass	2465	7.0(6.8–7.2)	3.5(3.5–3.6)
Kaibab National Forest			
U.S. Highway I-40	1800	7.0(6.8–7.2)	3.6(3.5–3.6)
Ten-X	2025	8.9(8.7–9.1)	3.3(3.2–3.4)
Tusayan	2045	9.5(9.4–9.7)	3.6(3.5–3.7)
Tusayan Landfill	2045	7.7(7.6–7.9)	3.6(3.6–3.7)
Williams 354 Road	2165	7.7(7.5–8.0)	3.2(3.1–3.3)

TABLE 4. Mean percentage of sound, hollow, and insect-damaged seeds[a] and mean number of total seeds per cone by location, Coconino and Kaibab national forests, Arizona, 1982.

National forest/Location	Sound seeds	Hollow seeds	Insect-damaged seeds	Total seeds
	$\bar{X}$ (95% confidence interval)			
Coconino National Forest	%	%	%	No.
Schnebly Hill	82(79–85)	15(12–18)	3 (1–4)	45(37–54)
Schnebly Plot	84(82–86)	15(13–16)	1 (0–2)	42(35–49)
U.S. Highway 89	2 (0–4)	8 (3–12)	91(85–97)	34(23–45)
Deadman Flat	38(29–46)	16(11–21)	46(35–57)	59(52–66)
Schultz Pass	41(27–55)	11 (6–16)	48(33–63)	57(48–66)
Kaibab National Forest				
U.S. Highway I-40	39(29–50)	29(20–38)	32(18–45)	48(39–57)
Ten-X	77(73–82)	16(14–19)	6 (2–10)	41(33–50)
Tusayan	83(79–86)	13(10–15)	5 (2–7)	53(47–60)
Tusayan Landfill	62(52–72)	27(17–36)	11 (3–20)	66(60–71)
Williams 354 Road	60(52–68)	33(25–42)	7 (2–12)	39(29–49)

[a]Mean percentages may not add to 100 because of rounding.

of Larson and Schubert (1970), the number of seeds per cone was 35% greater in all but one location.

Sound seed production varied significantly among areas (Table 4), and was noticeably less in areas with high incidences of *Conophthorus* and *Megastigmus* damage. The combined effect of all insects on the U.S. Highway 89 location essentially eliminated the production of viable seed for that location. Situations like this point out the need for a preliminary insect survey before an area is designated as a cone collection site. *Conophthorus* damage is easily seen at the time of cone collection; because a *Conophthorus*-infested cone usually produces no viable seed, the total seed production for each tree can be reduced by the percentage of infested cones on the tree. However, *Megastigimus* damage, and to a lesser extent *Dioryctria* and *Cydia* damage, can only be determined after the cones have been collected and dissected. If the *Megastigmus* damage approaches approximately 75% (e.g., Table 2, U.S. Highway 89 location), then probably less than 25% viable seed will be obtained from each cone. Thus, four times as many cones will have to be collected to produce the desired quantity of seed. Potential collection areas should be examined and a sample of cones assayed to determine insect damage before a major collection effort is initiated.

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